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Main achievements and perspectives of research into the early sea life period of Kamchatkan salmon species

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MAIN ACHIEVEMENTS AND PERSPECTIVES OF RESEARCH INTO THE EARLY SEA LIFE PERIOD OF KAMCHATKAN SALMON SPECIES.

V.I.Karpenko.

Research into the early sea life period of Kamchatkan salmons is centred in two areas: inshore waters of the Sea of Okhotsk and those of the Bering Sea. The main goal of the investigators is the assessment of the abundance of year classes and of conditions which determine it, linked as this factor is with the forecasting of the abundance of commercial runs. With this in view, a task was set to determine the causes and assess the extent of mortality of juveniles in estuaries and coastal waters in the main fisheries regions, which produce over 90% of the total catch of salmon in Kamchatka.

Investigations were initiated in Avachynskaya Bay in 1974, and beginning with 1975 they have been regularly conducted in Karaginskaya Bay of the Bering Sea. In 1987 these studies were set in two areas of western Kamchatka (Fig.1). The basic features of the biology of juveniles of fish salmon species (O.gorbusha, O.keta, O.nerka, O.kisutch and O.tshawytscha) were worked out in the coastal waters of the Bering Sea.They included the seasons of feeding and it is off shore migration откочевка [sorry, I don't know this term,ZK], growth, feeding, nutrient requirements and food links, as well as biocoenotic relationships of the juveniles of these salmon species. The dating and the length of the feeding migrations of the juveniles in the inshore waters vary among species (Table 1), which ensures more efficient utilization of the food base and determines the degree of competition, both intra- and interspecific. The juveniles of different species do not feed on the same prey species. Through the first weeks of sea life the main food of juvenile O.gorbuscha and O.keta are gammarids, cumaceans, mysids, cladocerans and copepods. In some years the diet of O.gorbuscha contains a high proportion of harpacticoids and fish larvae. With the course of migration into the open waters, juveniles change to feeding with marine species, the period of transfer varying in duration from one salmon species to another. O.gorbuscha is faster than O.keta in transferring to a diet of marine crustaceans, whereas O.kisutch, O.tshawytscha and, to a lesser extent, O.nerka become predatory from the first days of their sea life. The last named is capable of eating from 0.24 to 21% of migrating O.gorbuscha and O.keta.

Besides the "predator-prey" relationship, food relationship form between juvenile salmon due to the feeding on the same food. The greatest similarity

in diet exists between O.gorbuscha and O.keta (SP up to 80%). It is lesser among other species. However, due to the differences in the dates of migration and feeding season-, differences in the feeding activity of diel cycle, selective suitability and accessibility of the prey species, there is no intensification in competition between O.keta and O.gorbuscha during the first weeks after downstream migration, even in those years when O.gorbuscha is highly abundant. Competiton between these two species increases, as they migrate offshore. Thus, in 1978, in the open waters of the Karaginskaya Bay, their diet overlapped in composition in 16.8%. The main food of O.gorbuscha were euphasiids (59.3% of total bulk), whereas that of O.keta contained fish larvae (49.2%) and appendicularians (29.9%).

Table 1

Periods of feeding of juvenile salmon in different parts of inshore waters of Karaginskaya Bay

Species	Age	Littoral zone	Open waters
O.gorbuscha	0+	June 10(rarely 20) July	10 July- 10(20) Sept.
O.keta	0+	15(20) June - 30 July (15 August)	1 August - 20 Sept.
O.kisutch	1+, 2+, 3+	1 July - 15 August	1 August - 20 Sept.
O.nerka	0+	15 July - 10 August	10 August - 20 Sept.
"	1+, 2+	20 June - 25 July	25 July - 10 October
O.tschawytsha	1+, 2+	20 July - 30 August	1 Sept. - 15 October

Table 2

Mean water temperature (in °C) in littoral zone, biomass of food plankton and coefficient of growth of O.gorbuscha in the area of Karaginskaya Bay in 1976-1987

Year	Mean temperature		Mean biomass mg/m³		Coefficient of growth/E
	June	July	June	July	

Figures as in the original.

Juveniles of different species of salmon undergo their seaward migration in different physiological conditions. Thus, a large part of migrating juvenile O.gorbuscha still has large yolk remains (particularly juveniles of strong year classes). In O.keta the proportion of such fish is usually small, and among other species

there are no individuals in this condition.

Favourable feeding conditions, usually existing in the inshore waters of the Karaginskaya Bay, ensure fast rate of growth of the juveniles and its survival. Rate of growth of other species (O.gorbuscha and O.gorbuscha and O.keta) during the period of feeding in the littoral zone is slow and increases considerably after the offshore migration of the juveniles into the open part of the bays, where at the end of May - beginning of August it reaches it peak (Fig.2). With the beginning of migration of the juveniles into the open sea waters the rate of growth drops. The characteristics of the growth of O.gorbuscha and O.keta are determined by their ecological differences.

The main predators on juvenile salmon in Karaginskaya Bay are Salvelinus malma and Osmerus spp., as well as Salvelinus alpinus and various cottids. Predatory fishes feed on juvenile salmon mainly during the time of its mass migration and high density in the littoral zone. Salvelinus malma, S.alpinus and Osmerus most frequently prey on O.gorbuscha and O.keta, less often on young-of-the-year O.nerka. On the other hand, cottids prey on O.kisutch. Juvenile salmonids predominate in the diet of predators during migration of strong year classes; in that of S.malma in June, in Osmerus spp. in July-August. Predators usually eliminate small individuals, with considerable quantity of yolk remains. In individual years predatory fish of the river Khaylyulya remove up to 34% of migrating O.gorbuscha, and in inshore waters from 5 to 29% of O.gorbuscha and over 30% of O.keta. The predator pressure is most conspicuous on poor and middle strength year classes. For example, in 1980 during the feeding period in inshore waters predatory fishes eliminated 28.8% of migrating O.gorbuscha, resulting in the reduction of the run of adults in 1981 to 8 million fish. The reduction was manifest to a greater extent in ths southern part of the Bay, where recommended fishing for predators was not carried out.

A study of the extent of influence of the environmental factors on survival of juvenile salmon has shown that the most important of them is the hydrological regime of the inshore waters, food supply and abundance of predators. The importance of these factors is not the same in the life of different year classes, and in certain circumstances even one of them can be of decisive importance. For example, abnormally low water temperature in June in Ukinskaya Bay in 1977, 1979 and 1985, when ice floes were present up to the end of the month, led to significant mortality of migrating juvenile O.gorbuscha. As the result, commercial runs were poor in 1978, 1980 and 1986.

The influence of food supply can be seen from several facts (particularly if it coincides with low temperature). For example, the highest volumes of zooplankton biomass were recorded in 1979 and 1983. It could be expected that the runs of O.gorbuscha will be good in 1980 and 1984 (Table 2). However, because seaward migration of juveniles was relatively early and plankton developed late in 1979, the run of O.gorbuscha in 1980 was abnormally poor. In contrast, in 1984, when both these events coincided in time, the run was abnormally good. Similarly, both these processes occurred concurrently in 1986, causing a good run of O.gorbuscha in 1987.

In all, within the 13-year period, unfavourable conditions for feeding of juveniles occurred in 1976, 1978 and 1984. They were favourable in 1980, 1982 and 1986. In the first case the strength of the offspring generation was lower than, or equal to, that of the parental generation; in the second it was higher by about an order of magnitude.

Taking into account the year strength and condition of feeding for the juveniles in the inshore waters, a method was perfected for the forecasting of the strength of the commercial run of O.gorbuscha a year in advance. To improve the forecast, in addition to the data on the abundance of parental generation, taken into account were also abundance of juveniles in the littoral zone, temperature and salinity regime, condition of the food base, abundance of predators, as well as the growth characteristics of the juveniles. To accommodate these data, equations in Table 3 were developed. Forecasting of spawning runs of O.gorbuscha with the aid of these parameters produced satisfactory results for 6 year classes. It was unsatisfactory only during the years with abnormal conditions (i.e. for the year classes of 1978 and 1984).

The direction of further studies involves fine-tuning and extending work in the standard area of Karaginskaya Bay and in the costal waters of the Sea of Okhotsk off Kamchatka. First cruises into these areas, carried out last summer, gave positive results. The timing and the locality of investigations were more precisely defined, new fishing gear was tested and some data were collected on the ecology of these areas.

Because of the differences in the level of our knowledge of the biology of juvenile salmon, in the main fishing areas the goals of studies for the next 10 years will include in eastern Kamchatka:

- annual assessment of abundance, biological composition and degree of elimination of juveniles in the system river-estuary-littoral.

Of greatest importance are the conditions of feeding of year classes. The young of 1987 were observed to have the highest rate of growth: O.gorbuscha and O.keta reached the size of 7-9 and 5-8 cm respectively in 35-40 days. Although the seaward migration of juveniles began, while ice floes were sitll present in the littoral zone, intensive warming prompted vigorous development of plankton and caused high rate of growth of the juveniles.

Table 3

Equations describing the relationship between the abundance of runs of O.gorbuscha in Karaginskaya area and changes in the controlling environmental parameters.

Equations as in original

R - size of run in millions of pieces;

E - Abundance of spawners, in millions of pieces;

K - relative abundance of juveniles in the littoral, in numbers of fish.

L - mean length of juveniles in June, in cm.

N_o - abundance of migrating juveniles, in millions

B_{VII} - biomass of food plankton in July, mg/m³

a, b, c - coefficients; $x_1 \ldots x_i$ - controlling parameters.

Table 4

Intensity (no.of specimens) and prevalence (%) of infection of juvenile gorbuscha and O.keta with larval trematodes in 1987

Area and month of catch	O.gorbuscha	O.keta
Littoral zone, July		
Open waters of bays, July	Figures as in original	
Karaginskaya Bay, July		
October		

enumerator - prevalence (%); denominator - intensity of infection (no.of specimens)
In brackets, numbers of fish examined.

- assessment of physiological readiness of juveniles to life in sea water and search for the criteria of their viability.

During recent years data were collected on the contents of biochemical constituents in the body of juveniles, reflecting the level of food available to them. It has been determined that, when food supplies are high, the body of a juvenile cotains, as the migration proceeds, increasing quantities of fat and protein. The energy contents of musculature increases, water content drops. When food supplies are low, the opposite can be observed.The direction in which the change of the biochemical indeces proceeds allows to judge the course of metabolism and to anticipate the level of viability of individual year classes.

In 1987, T.I.Kalyuzhnaya conducted studies of some haematological indeces of juveniles belonging to four species: O.gornuscha, O.keta, O.nerka and O.kisutch. She studied blood picture, size of erythrocytes and leucocyte formula during the process of migration downstream and offshore from the littoral into the open sea. Most interesting data were obtained for O.gorbuscha and O.keta. To begin with, O.gorbuscha was found to consist of two physiologically distinct groups, which arbitrarily were named "freshwater" and "marine". The fish of the former are characterized by large numbers of enucleate and amitotic erythrocytes, as well as well as of lympho- and leucoblasts. In fish of the latter group predominated mature erythrocytes and lymphocytes. With the progress of the offshore migration and adaptation of juveniles to sea water, processes of the haemopoietic system became stabilized. In juvenile O.keta in the sea erythropoiesis diminishes and lympho- and leucopoiesis becomes vigorous. Further investigations are directed toward determination of the critical phase of haemopoiesis, which would determine adaptation to life in sea water,and toward search for criteria of viability.

- determination of the extent of influence of environmental factors on year class strength.

At present, only the extent of elimination of juvenile salmon by predatory fish can be determined with sufficient accuracy. In 1987 this extent in the river was: O.gorbuscha 12%, in the littoral 15-20%; for O.keta over 30%. This the third highest index for O.gorbuscha (after 1980 and 1978) and highest for O.keta of all the years of investigation. Also taken into account was the level of food suppy and characteristics of hydrological regime. Moreover, in 1987, was observed mass infection of juvenile O.gorbuscha and O.keta with trematode larvae in some

parts of Karaginskaya Bay (Table 4). Unfortunately, it proved impossible to identify them to the level of the species. Demersal animals, the proportion of which in the diet of juveniles has risen considerably in recent years, could have provided the source of infection. Birds and predatory fishes serve as definitive hosts. It appears that a part of infected juveniles dies. A parasite control will be necessary in the future. Lesions caused by trematode larvae can be used as biological tags in studies on sea migrations of salmon.

- study of the role played by juvenile salmon in the littoral fish community.

The importance of juvenile salmon in feeding of predatory fishes, as well as interspecific relationships of juveniles have already been commented upon. Here we would like to dwell on the assessment of the role of these species in determining the abundance of some other commercial fishes, Pacific herring in particular. Larvae and young-of-the-year herring began to appear in the food of juvenile salmon since 1977. In 1981-1983 they constituted in some species from 1.4 to 86.1% of the total food mass. Feeding assumed mass proportions, up to 270 larvae and up to 60 young-of-the-year being found in a single stomach. It appears that this feeding resulted in high mortality of larvae of the 1983 year class, leading to the drop in the numbers of young-of-the year, which by the fall were 2-5 fewer than in 1981 and 1983 (Table 5). It is evident, however, that one cannot draw any firm conclusions on the nature and, particularly, intensity of relationships between herring and the salmons on the basis of this information alone.

Investigations in western Kamchatka are in their initial stages and should include:

- study of ecology of juvenile salmon and conditions of its feeding in the inshore waters;
- discovery and assessment of main factor- limiting survival of juveniles during the first weeks in the sea;
- development of the method of applying the results of studies on the early sea life of juveniles to improvement in forecasting the runs of adult salmon.

Current work involves development of methods to be used in this study, only first and preliminary results have been obtained.

Paratunskiy Fish Farm and hatchery will begin production in the next few years. It will produce O.keta, O.kisutch and O.nerka. The projected output of the farm will consist of 21 million of smolts: 20.8 million O.keta 1 g in weight and 0.1 million of both O.keta and O.kisutch 10 g in weight. The effectiveness of the work

of this farm will to a large extent depend on the survival of released juveniles in the river Paratunka and in Avachynskaya Bay, where they will be under the influence of the local hydrological conditions and will have to cope with the food supply situation and predator pressure. We have attempted to determine as much as possible food requirements of the cultured juveniles during their stay in Avachynskaya Bay. The caculation was based on both literature and our own data.

Table 5

Abundance of larvae and young-of-the-year of herring and their consumption by juvenile salmon

Year	Larvae, No.	Consumption (arbitrary units)	Young-of-the-year No.
Figures as in the original text			

Table 6

The quantity of food (t) required for juvenile salmon from Paratunskiy Farm during their stay in Avachinskaya Bay

Component	O.keta	O.kisutch	O.nerka	Total
Polychaetes				
Crustaceans				
Insects				
Fishes		Figures as in the original text		
Other				
Total				

+ = less than 0.1 t

It was assumed that O.keta and O.kisutch feed in the Bay about a month and a half and O.nerka one month, reaching the size of 8 cm and 4 g, 16 cm and 50 g, and 13.5 cm and 25 g, respectively. Taking into account daily rations, numbers of juveniles (disregarding their elimination) and duration of feeding, the quantity of food required was calculated at 336.3 t (Table 6). When elimination (mortality) is 50%, 252.3 t of food will be utilized, of which 94.6% will be used by O.keta, 3.8% by O.kisutch and 1.6% by O.nerka.

As can be seen, a study of only one factor, i.e. food supply for juveniles, has demonstrated the importance of the assessment of productivity of the waters

in this nursery area. The survival of juveniles will depend on the date of release, which should be synchronized with the favourable abiotic and biotic conditions in the littoral zone. A study of these questions is necessary for management of fish culture techniques, leading to optimization of technology and improvement of effectiveness in the work of Paratunskiy Fish Farm. Similar studies should be instigated in other areas, in which building of fish farms is anticipated.

The results of the studies on the early sea life period of salmon should be utilized: (1) in monitoring wild populations; (2) in assessing living conditions of cultured juveniles, leading to increase in the size of spawning runs of adults of artificially cultured salmon.

Figure captions:

Fig.1. Localities of investigations.

Fig.2. Changes in the instant linear growth rate of juvenile O.gorbuscha (1) and O.keta (2).

Рис. 1. Районы исследований.

Fig. 1. Localities of investigations.

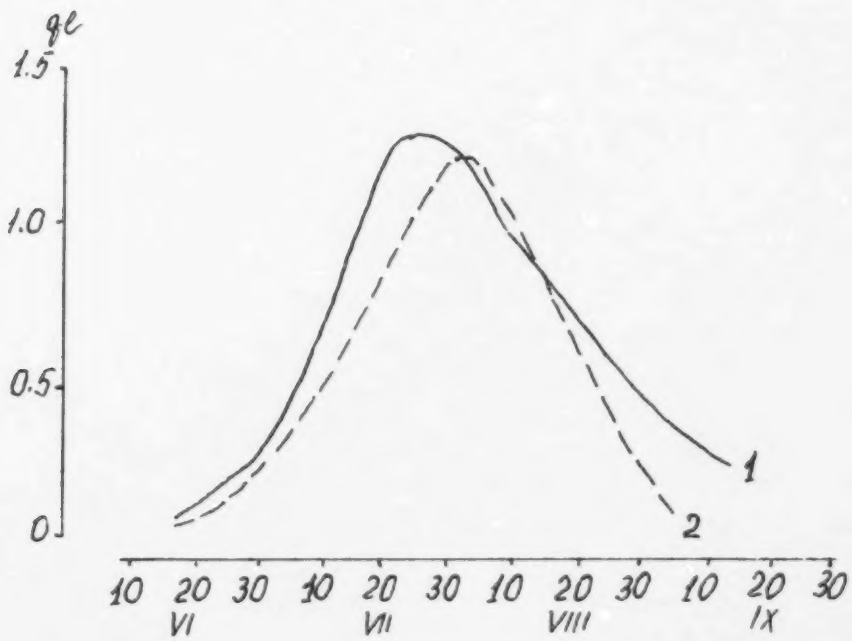

Рис. 2. Изменение мгновенной скорости линейного роста молоди горбуши (I) и кеты (2).

Fig. 2. Changes in the instant linear growth rate of juvenile O.gorbuscha (1) and O.keta (2).

Table 2

Mean water temperature (in °C) in littoral zone, biomass of food plankton and coefficient of growth of *O. gorbuscha* in the area of Karaginskaya Bay in 1976-1987.

Year	Mean temperature		Mean biomass mg/m3		Coefficient of growth/E
	June	July	June	July	
1975	9.9	11.9	75.4	103.4	7.3
1976		11.8			4.1
1977		12.4		172.6	1.3
1978	7.2	10.4	35.1	135.7	4.8
1979		10.3		424.2	0.7
1980	6.3	12.0	198.5	320.2	4.3
1981	15.9	13.8	104.5	286.5	9.7
1982	9.8	11.0	255.4	130.2	1.6
1983	10.4	13.1	744.7	708.5	16.1
1984				249.0	3.5
1985	9.8	12.6	130.0	194.5	8.9
1986	12.3	12.0	137.9	194.5	8.9

Table 4

Intensity (no. of specimens) and prevalence (%) of infection of juvenile *O. gorbuscha* and *O. keta* with larval trematodes in 1987

Area and month of catch	O. gorbuscha	O. keta
Littoral zone, July	2.5 / 3-31 (242)	0.5 / 11-13 769
Open waters of bays, July	13.8 / 31-163 (58)	(2)
Karaginskaya Bay, July	0.5 / 7-52 (412)	3.2 / 9-37 (158)
Karaginskaya Bay, October	23.2 / 9-68 (54)	11.0 / 5-38 (100)

enumerator - prevalence (%); demoninator - intensity of infection (no. of specimens); in brackets, no. of fish examined

Table 5

Abundance of larvae and young-of-the year of herring and their consumption by juvenile salmon

Year	Larvae, No.	Consumption (arbitrary units)	Young-of-the-year No.
1978	6254		6.4
1980	29411	2.15	27.4
1981	11613	40.77	29.3
1982	29761	1589.33	14.7
1983	42209	134.90	82.6
1985	21873		435.6

Table 6

Quantity of food (t) required for juvenile salmon from Paratunskiy Farm during their stay in Avachinskaya Bay

Component	O. keta	O. kistuch	O. nerka	Total
Polychaetes	14.3	0	+	14.8
Crustaceans	159.8	7.2	3.7	170.7
Insects	86.9	2.7	0.9	90.5
Fishes	9.6	0.9	0.2	10.7
Other	47.7	1.5	0.4	49.6
Total	318.3	12.8	5.2	336.3

+ = (less than 0.1 t)